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A decade of research collaboration on safety climate at Texas A&M University

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Over the past decade, faculty in the Department of Psychology who specialize in industrial-organizational (IO) psychology[1] have collaborated with the Mary Kay O'Connor Process Safety Center on the topic of safety climate[2]. In this paper and presentation, we will review the strides made in safety climate research over the last decade, focusing in particular on the work produced at Texas A&M University. The goals of this retrospective are: (a) to bring MKOPSC symposium attendees up-to-date on the state-of-the-science for safety climate

[1] Industrial-organizational (IO) psychology is the scientific study of how people act in the workplace, how they create workplace processes and products, and how workplace experiences affect people's well-being. Our professional society, the Society for Industrial and Organizational Psychology (SIOP; www.siop.org), uses the tagline "science for a smarter workplace." IO psychologists attempt to improve workplaces in order to improve people's well-being and organizational success. Both are important to IO psychologists as these are intertwined and mutually reinforcing—a successful organization can hire and pay more people and give them positive workplace experiences; workers whose well-being is respected and supported by organizations can help organizations be more successful.

[2] Organizational scientists distinguish between culture and climate. Ostroff, Kinicki, and Muhammad (2012) define climate as employee perceptions of the organizational expectations about f workplace behaviors, norms, and attitudes, whereas culture is the shared motives, identities, and values that arise from employees' common experiences. When discussing the differences between climate and culture, Ostroff et al. noted, "Whereas climate is about experiential descriptions of perceptions of *what happens*, culture helps define *why these things happen*" (p. 566, emphasis added). Typically, when laypeople use the term "culture," they are encompassing both culture and climate from organizational science. Here, we use the term "climate" to be consistent with organizational science practices and because the methods we use in our research are consistent with the best practices for assessing climate.

research, (b) to demonstrate the value of MKOPSC's investment in social science research, and (c) to encourage continued collaboration between social scientists and engineers in improving safety climate.

Overview of Safety Climate Concepts

Before reviewing research that has been supported by MKOPSC, we first review foundational safety climate concepts.

What is safety climate?

Organizational climate refers to the employees' shared perceptions of organizational policies, procedures, and practices about some component of organizational life (Ostroff, Kinicki, & Tamkins, 2003; Ostroff, Kinicki, & Muhammad, 2012; Reichers & Schneider, 1990; Schneider & Reichers, 1983). Climate guides employees about which behaviors are rewarded, supported, and expected in the workplace (O'Reilly & Chatman, 1996; Schneider & Reichers, 1983). Organizational scientists usually examine climate for specific aspects of organizations because these different domains in organizations have different policies, procedures, and practices. That is, there is not a monolithic organizational climate, but rather a series of "climates for" different parts of the organization (e.g., safety, diversity, service, etc.; Schneider & Reichers, 1983). Safety climate is one of the most studied of these subtypes of organizational climate (Schneider, Erhart, & Macey, 2013).

Thus, safety climate is employees' shared perceptions of policies, procedures, and practices regarding workplace safety (Zohar, 2003). Many researchers consider safety climate to be multidimensional, but there is no consensus on its underlying factors (Guldenmund, 2000). What is clear, however, is that management commitment to safety is a key (and possibly superordinate) element of safety climate (Beus, Muñoz, Arthur, & Payne, 2013; Flin, Mearns, O'Connor, & Bryden, 2000; Zohar, 2003). For example, our research showed that management's commitment to safety is manifested in organizations in several ways, including: safety communication, coworker safety practices, safety training, employee involvement in safety, safety rewards, and safety equipment and housekeeping (Beus et al., 2013).

Although we usually focus on the *shared* perceptions from employees to represent climate, the individual's responses are also useful and important information. An individual's safety climate score (i.e., the mean of the items that measure safety climate) has been referred to as psychological climate (James & Jones, 1974). Psychological climate has significant utility as it predicts both workplace safety behavior and injuries (Beus, Payne, Bergman, & Arthur, 2010; Nahrgang, Morgeson, & Hofmann, 2011).

Key features of safety climate

When describing safety climate, two features are key: level and strength. Level is the "goodness" or "badness" of safety climate for a work group, usually defined as all of the individuals who report to the same supervisor. It is calculated as the average of the individual employee responses for the safety climate measure for a group (Chan, 1998; Schneider, Salvaggio, & Subirats, 2002). Strength represents the extent to which a workgroup agrees about the level of safety climate. When there is less within-group variability, there is more agreement among the employees within the group; thus, the climate is stronger (Schneider et al., 2002). Climate strength is calculated as the standard deviation of the employees' responses within a group to a safety climate measure (Schneider et al., 2002).

These two features—level and strength—are important to understanding safety climate and its ability to predict organizational outcomes, employee behavior, and unsafe events. Safety climate level, unsurprisingly, is linked with a variety of outcomes, such that higher (better) safety climates are linked to better outcomes (Bergman, Payne, Taylor, & Beus, 2014; Beus, Payne, et al., 2010; Christian, Bradley, Wallace, & Burke, 2009; Nahrgang et al., 2011). On the other hand, safety climate strength is conceptualized as a moderator of the safety climate level → outcomes relationship. This is because safety climate strength, as a measure of agreement, shows the extent to which a group's score is relevant to each member of the group; higher agreement means that the group's average score is more representative of each member. When agreement is high, the members of the group are on the same page regarding safety climate level. Further, when agreement is high, there is greater normative pressure for people to act similarly (O'Reilly & Chatman, 1996; Schneider et al., 2002). Research supports these contentions, demonstrating that the effect of climate level on organizational outcomes is stronger when climate strength is high than when climate strength is low (Schneider et al., 2002).

Common safety climate assessment practices

Like most climate assessments, safety climate is usually measured with employee surveys. The surveys are conducted with individual employees because even though safety climate is *shared* perceptions, it is the individual employee perceptions that are held in common within a group. Then, safety climate level and strength are calculated for each group.

There are many safety climate measures in the safety literature (e.g., Beus et al., 2013, Zohar & Luria, 2005), as well as a vast number that are proprietary and homegrown in organizations worldwide. As noted above, safety climate is considered to be multidimensional, but management commitment to safety is an essential component. Most safety climate measures reflect this, measuring some aspects of management commitment to safety as well as (usually) some additional aspects. Safety climate measures do not have to be long to be useful as demonstrated by studies with instruments composed of about ten items (Bergman et al., 2014;

Hofmann & Stetzer, 1996; Zohar, 2002). Finally, most safety climate measures are conducted using a five-point Likert-type scale (e.g., five response options ranging from "strongly disagree" to "strongly agree").

Review of Safety Climate Research from Texas A&M

Now that we've provided an overview of safety climate and its assessment, we will review some of the research conducted at TAMU in collaboration with MKOPSC. We have selected key lessons learned to highlight the contributions of this long and fruitful collaboration.

Construct clarity is essential to a good measurement system

Many safety climate surveys also include other, related topics beyond safety climate. This is an acceptable and common practice because it (a) allows for contemporaneous correlations between safety climate and possible drivers (e.g., safety attitudes, risk tolerance, recent unsafe experiences) and (b) reduces the number of survey requests of employees. However, our research shows that when developing the survey and reporting its results, it is important that the different themes on the survey are separated.

In a meta-analysis[3] conducted in our lab (Beus, Payne, et al., 2010), we examined the effect of construct contamination and construct deficiency on the safety climate-injury relationship. Contamination is the inclusion of extraneous, systematic variance in the measure; in practice, this often occurs through the inclusion of questions about something else, even if it is somewhat related (e.g., perceived risk with a measure of safety climate). Deficiency is the exclusion of relevant systematic variance in the measure; in practice, this often occurs by overlooking important topics when constructing the questionnaire. Our analyses showed that

[3] A meta-analysis is a quantitative summary of a set of studies. This summary finds the average relationships across the studies. It is useful because the set of studies together can overcome the limitations of any single study (e.g., small sample size, cultural effects of a single country study).

contamination of the safety climate measures (e.g., the inclusion of perceived risk) inflated the safety climate-injury relationship while deficiency of the safety climate measure reduced this relationship. At first blush, it might seem advisable to create contaminated measures. However, this is a bad strategy because it makes it difficult to know what the drivers really are for unsafe incidents and it is poorly conducted science. This separation of topics (or as they are called in psychological research, "constructs") is essential so a clear assessment of safety climate can be made and so the results demonstrate what factors really are linked to safety in the workplace. Thus, distinguishing between assessments (even within the same survey) of multiple safety-related variables can help organizational leadership make good data-driven decisions on where investments should be made and new resources deployed.

Safety climate should be measured frequently

Our meta-analysis also demonstrated that as the time over which injuries were aggregated lengthened, the correlation between safety climate and injuries were reduced (Beus, Payne, et al., 2010). This led us to wonder about the "shelf life" of a safety climate assessment. We wanted to know when the relationship between safety climate and unsafe incidents expires (Bergman et al., 2014). That is, when does an assessment of safety climate go past its useful date? When are the data no longer "fresh"? We examined this relationship in two ways: with unsafe incidents as the predictor (i.e., unsafe incidents from the two years prior to the safety climate assessment) and with unsafe incidents as the criterion (i.e., unsafe incidents from the two years following the safety climate assessment). Thus, both the leading and lagging relationships were examined which we had previous speculated about (Payne, Bergman, Beus, Rodriguez, & Henning, 2009) and demonstrated empirical support for (Beus, Payne, et al., 2010).

We divided the incidents into monthly periods and used these monthly periods to determine when the safety climate-safety incident relationships were no longer significant. Our analyses showed that safety climate predicts incidents of different severity levels (e.g., damage less than $10000 or first aid; damage more than $10000 or severe injuries), but safety climate predicts the most severe incidents over the shortest period of time. Similarly, when incidents predict safety climate, the more severe incidents have the shortest predictive period. For the most critical relationship (climate predicting more severe incidents), the predictive power is strongest in the first month after the assessment and drops off quickly, such that the ability of a safety climate assessment to predict incidents expires after 3 months.

Thus, organizations should assess safety climate at least once a quarter, but best practice is assessment monthly (if not more often). Further, organizations need to attend to the aggregation period they use in reporting and analyzing incident rates. Yearly count of incidents, for example, would make it seem like safety climate cannot predict severe incidents and thus would make safety climate assessment programs seem like a poor investment. Yet a shorter aggregation period (monthly or quarterly) would reveal very different effects and show the utility of safety climate assessment programs and how they can be used to identify organizational hot spots that need just-in-time attention.

Employee retention influences safety climate strength

In our review of key concepts in safety climate, we noted that safety climate strength reflects the amount of agreement in a group about safety climate. It is the variability in safety climate scores around the group mean of those scores. This is important because stronger climates create greater normative pressure on employees to behave in certain ways. A strong, high (i.e., good) safety climate is a useful way of encouraging good safety behavior in organizations.

We conducted research on the relationship between group tenure and safety climate strength (Beus, Bergman, & Payne, 2010). We wanted to know: if groups are made up of people who have worked for the company longer, will safety climate be stronger? Our research demonstrated that this is the case: groups that have higher average tenure also have stronger safety climates. Further, our research showed that at higher levels of worksite tenure, smaller increases in the group's average tenure improved climate strength to a greater extent than at lower levels of worksite tenure. This demonstrates another reason why employee retention is critical to organizational success. Not only does increased retention result in greater organizational knowledge retention and higher return on investment in workers, but it also leads to stronger safety climates.

Are industry-specific measures of safety climate necessary?

In our meta-analytic review of the literature, we identified 61 unique safety climate measures that had been used in research (Beus, Payne, et al., 2010). In a follow-up systematic review of over 1500 items within these measures (Beus, Payne, & Arthur, 2011), 33 of the 61 measures included at least one industry-specific item (e.g., "Policies regarding not recapping used needles are posted;" Day, 1999, p. 88), whereas 28 measures consisted of only general items (e.g., "A busy situation does not prevent supervisors from intervening if someone acts against safety rules;" Varonen & Mattila, 2000, p. 765). Although other safety climate researchers have advocated for the development of industry-specific safety climate measures (Zohar, 2010), we wondered how much of a difference it makes to use an industry-specific measures and if it is really necessary to include them.

To answer this empirical question, we examined safety climate in five different kinds of university laboratories: animal biological, biological, chemical, human subjects/computer, and mechanical/electrical (Keiser & Payne, 2017). Each type of laboratory served as a corollary to a specific industry as the labs have unique hazards, risks, and corresponding policies and procedures. Using survey responses from over 700 laboratory personnel, we contrasted the correlations we calculated between a general measure of safety climate (i.e., no lab-specific cues) and various self-reported safety-related outcomes (knowledge, motivation, behavior, and injuries) to the correlations we calculated between each laboratory-specific safety climate measure and the same outcomes. We found that the inclusion of context-specific information did not have a dramatic influence on the relationships tested and contrary to expectation it was most helpful for less, rather than more, safety-salient contexts (Keiser & Payne, 2017). Thus, it seems that it is not necessary to use an industry-specific measure of safety climate when predicting self-reported safety-related outcomes.

That said, much of our research has taken place with the oil and gas and chemical processing industry. Within this industry (as well as others), there is a strong concern about process safety which could be simply described as keeping the process safe. In other words, ensuring that chemicals and hazards remain contained and are combined in ways that are consistent with regulations. Violations of process safety include leaks, spills, and releases of toxic substances (Hopkins, 2009), as well as fires and explosions. Building on the safety climate research, process safety experts propose a process safety climate which can be defined as employees' perceptions of the policies, procedures, and practices concerning process safety. Some indicators of a weak process safety climate include a lack of operating discipline, toleration of serious deviations from safe operating practices, and complacency toward serious process safety risks (BP Baker Report, 2007). In our research, we have found that a short (12 item) process safety climate measure relates significantly to process safety incidents including environmental impact, fire/explosions, and property damage (Payne, Bergman, Rodriguez, Beus, & Henning, 2010). Some of the most useful process safety climate items concerned preventing large backlogs, conducting routine housekeeping, and promptly correcting health and safety concerns.

Moving forward: What can psychology do to support MKOPSC and its members?

This brief look at the research conducted under the auspices of MKOPSC by members of the Department of Psychology at Texas A&M University has indicated some of the key features of what psychologists can bring to bear on the question of industrial safety—whether process safety or personal safety. We are convinced that under the right circumstances, measured human elements can be a key process safety indicator, just as measured engineered and process elements are. To that end, we provide a short list of some of the research collaborations that we can create with MKOPSC member organizations.

(a) *Assessment of safety climate*: From the review above, this is clearly one of our strongest capabilities. We are able to assess the shared norms and expectations about safety in the work setting. When poor measurement of safety climate occurs, not only might it undersell the importance of safety climate but could also lead to erroneous conclusions about where negative safety norms exist. Expert measurement for safety climate is necessary to use this human-based data to improve work conditions. We are also able to conduct statistical analyses to demonstrate how safety climate is related to unsafe incidents.

(b) *Development and assessment of training programs*: IO psychologists have the skill set to develop and assess training programs. Although the development of content for training programs requires subject matter experts (i.e., you do not want an IO psychologist to tell people how to do lockout/tagout or to vent a system—you need experts for that), how content should be presented for the best learning is within IO psychologists' purview. Additionally, the assessment of training programs—determining whether learning has occurred and if that learning matters to job performance—is one of the bread-and-butter skills of IO psychologists.

(c) *Team processes:* Rarely do individuals work alone anymore. Because of the complexity of processes and tasks, different people must come together in an efficient and effective manner to solve problems. However, this task work has to be coupled with team work. That is, efficiency and effectiveness isn't just finding the right solution; it's also about working together well. IO psychologists can assess team processes and conduct teamwork interventions to improve teamwork, which will ultimately improve safety.

Conclusion

Our program of research on safety climate has revealed that construct clarity is essential to a good measurement system. Brief measures of safety climate can be sufficient, but it is important to ensure that they are not contaminated or deficient. Safety climate should be measured frequently, possibly as frequently as every month. Safety climate strength, or the extent to which workgroups agree about the level of safety climate, is associated with turnover, such that work groups that have higher average tenure have stronger safety climates. Finally, it does not appear necessary to use industry-specific measures of safety climate when predicting general safety outcomes; however, industry-specific measures may be especially useful when predicting industry-specific outcomes (e.g., process safety climate with process safety outcomes).

Over the last decade, MKOPSC and the Department of Psychology have created a fruitful and influential program of research on safety climate. This work can only be accomplished via collaboration between safety practitioners and social scientists. As part of this retrospective, we must thank MKOPSC and its membership for their support and interest in our work. We look forward to partnerships with member organizations to answer questions essential to the human side of safety practice.

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